Electromagnetic Launcher to Mars

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Presentation Outline

- Project Background
- NTR Comparison
- Project Specifics and Constraints
- Launcher Infrastructure
- Launcher Design Options 1-5
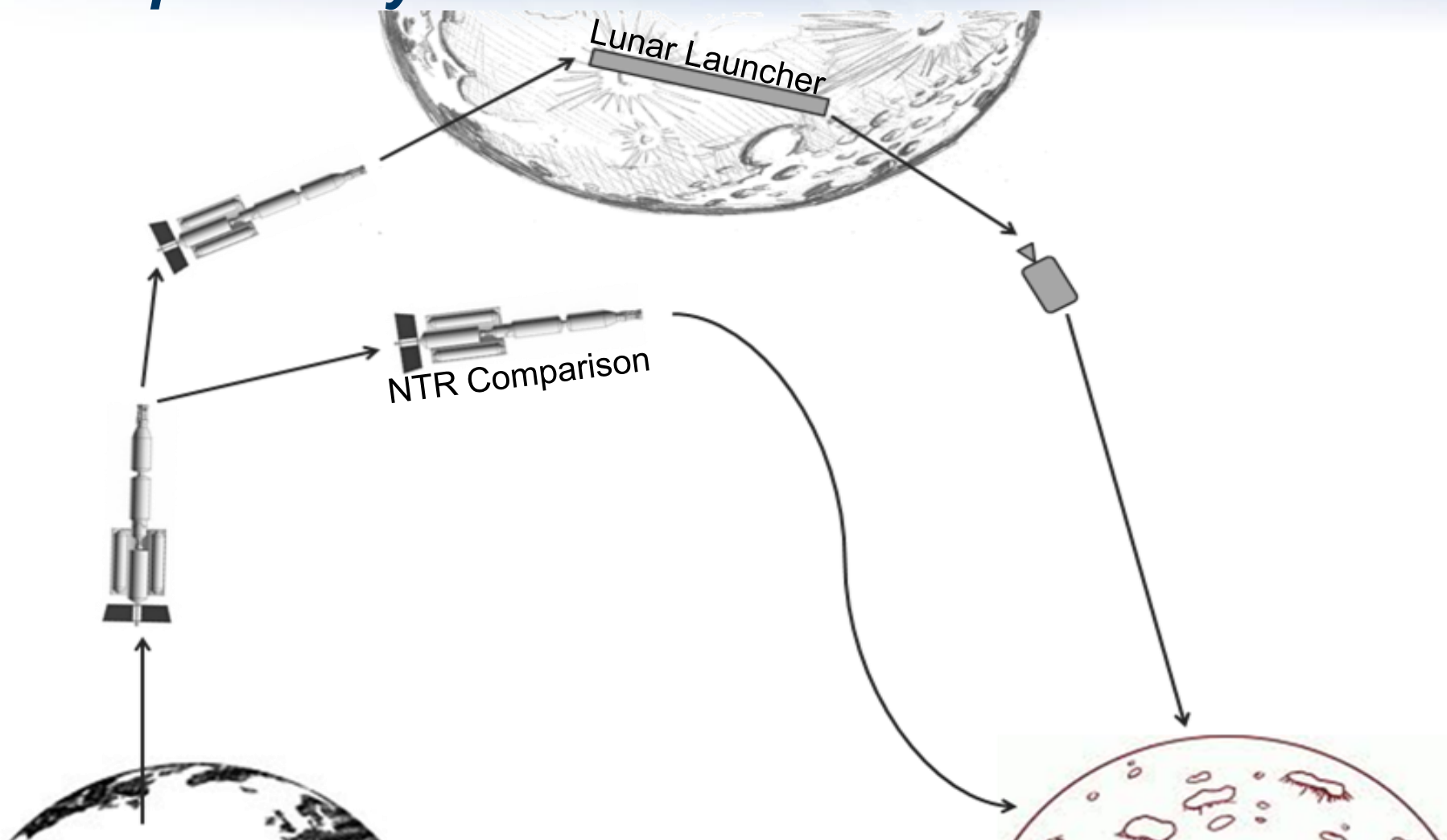- Comparisons
- Discussion
- Conclusion

Project Background

- NTR to Mars

  - Enabling technology for human exploration of Mars

  - The mass of the propellant for the <u>entire</u> NTR mission must be carried on-board

  - Incremental payload increase = significant structural and propellant mass increases

  - Creating and sustaining an outpost on Mars will require frequent cargo launches

Project Background

- Design an electromagnetic lunar launcher as an alternative method to perform interplanetary transfer
    - Requiring electricity for launch instead of propellant

- Launch cargo to Mars
    - Minimal on-board propellant and structural requirements
    - Incremental increase in payload = incremental increase in power requirements
    - Ability to increase frequency of launch to meet mission requirements
    - Flexible for other interplanetary launches in the future

Interplanetary Lunar Launcher

Lunar Launcher

NTR Comparison

NTR Comparison

- Payload: 100 tons

- Fuel: 198 tons
  - Liquid Hydrogen fuel
  - Must carry all fuel to get from LEO to Mars orbit

- TOF to Mars: 100-140 days
- IMLEO = 394-429 metric tons
- ΔV = 8.4-9.1 km/s

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Electromagnetic Lunar Launcher Project Specifics

- Payload: 100 tons
  - Dimensions:
    - Diameter=8.5 m
    - Length=26 m
  - Assumed 100 tons of liquid hydrogen
  - Launched from Earth to LEO with NTR and NTR used to get to LLO
- Lunar Restricted Forces: 15 G's
  - Maximum ΔV=5 km/s
- Track Length: 88 km

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Project Specific - contd

- Timeline is 50 years out

- Lunar base exists

- Consistent need for cargo launches to Mars

- Commercialization of Earth-based launches

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- Orbital Mechanics Assumptions
  - NTR ISP of 850 s
  - NTR has 214 N of thrust
  - Impulsive burns for entrance into Martian orbit
  - Once a day launch

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Launcher Infrastructure

- Surface Power
    - High Temperature Gas Reactor - ~30 MWe
    - System mass - ~150 metric tons

- Energy Storage
    - Aluminum electrolytic capacitors

- Location
    - Far side of the moon

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Design Options

- Option 1: Maglev

- Option 2: In-Situ Maglev

- Option 3: Linear Synchronous Motors

- Option 4: Conducting Glass Road

- Option 5: Coil Launcher

Option1: Maglev
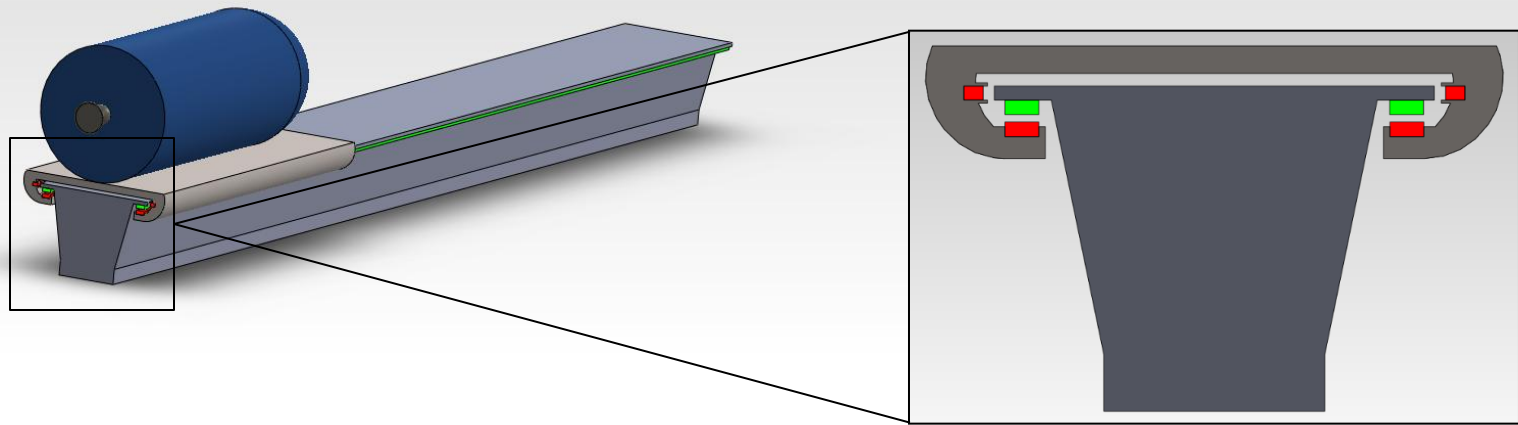
Levitation System

Electromagnetic Suspension (EMS)

- Electromagnets located on the sled

- Coils line the track

- Interaction results in constant levitation
 - Airgap between 1-10 cm

Electrodynamic Suspension (EDS)

- Superconducting magnets on the sled

- Electromagnetic coils line the track

- Must have wheels to move sled until lift-off speed is reached

Option 1: Maglev

- Design based on current technology
  - German Transrapid
  - South Korean UMP
  - Japanese MLX

- Everything made on Earth and sent to LLO
  - Track: aluminum
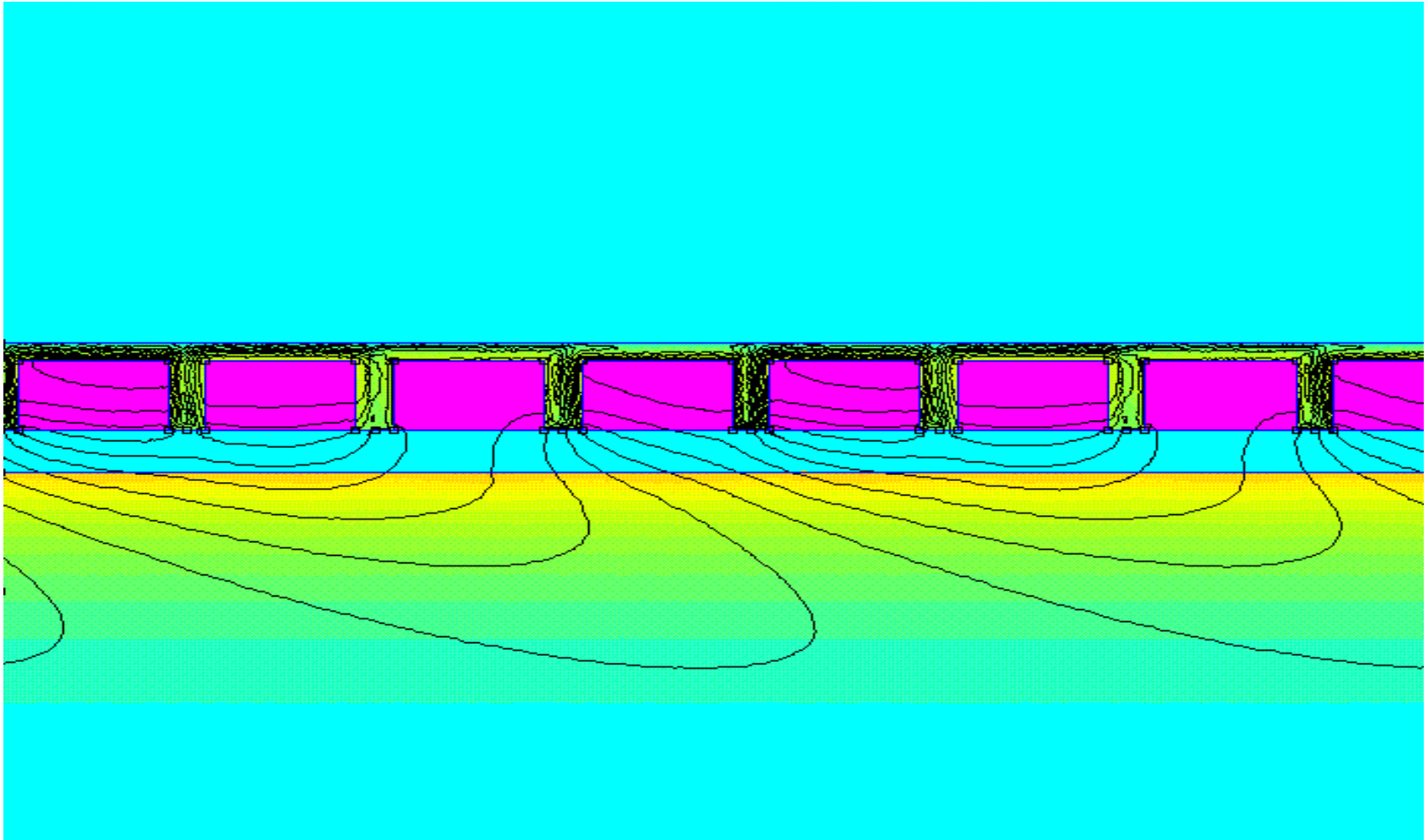 - Sled: aluminum
  - Structure: carbon steel

Option 2: In-Situ Maglev
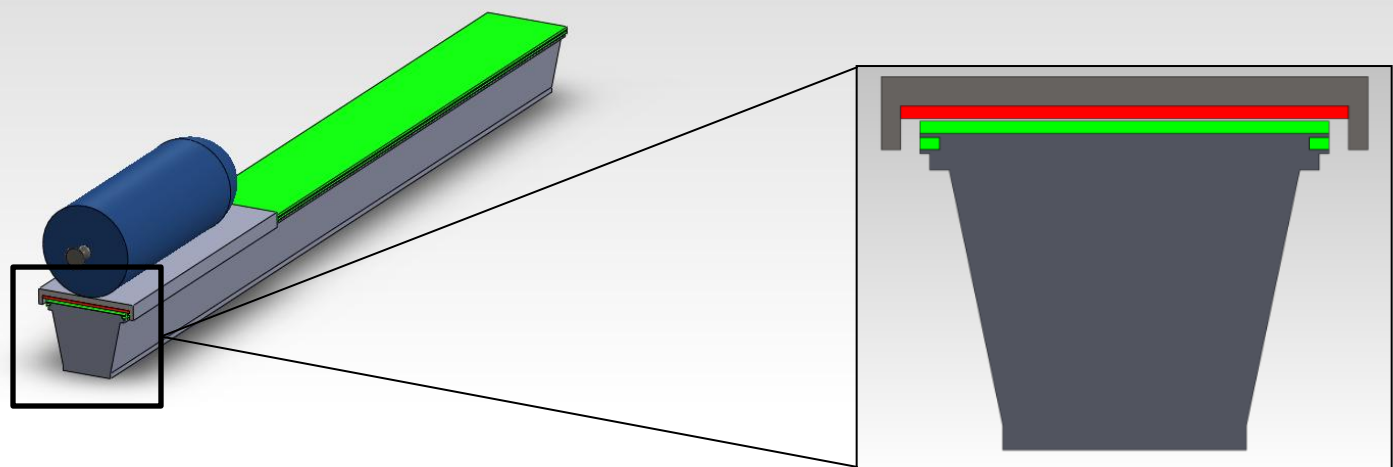
Option 2: In-Situ Maglev

- Certain components or materials still on Earth
    - Superconducting magnets
    - Reactors

- The rest made from lunar materials
    - Sled: aluminum
    - Track: iron
    - Structure: sulfur concrete
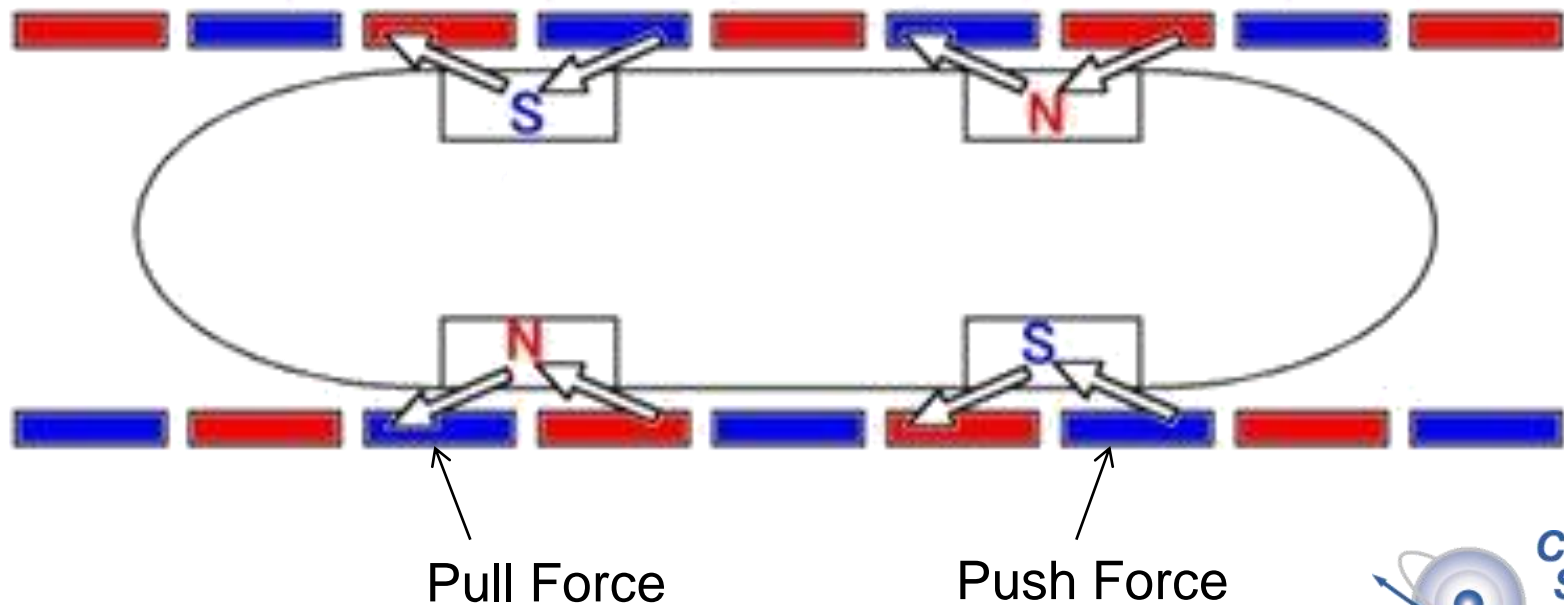
Option 3: Linear Synchronous Motors

Lines: electric potential
Color: magnetic flux density (blue to pink, low to high)

How LSM Work

- Contains a magnetic source within the motor

- Thrust force is produced by interaction between the armature current and magnetic field

Pull Force   Push Force

Option 4: Conducting Glass Road

- Conductive glass roadway
  - Add in-situ aluminum to make the road conductive
  - Sinter roadway to make regolith into glass

- Superconducting magnets, receiver, radiators, and cargo on sled

- Power beaming to power sled
  - Entire amount of power must be beamed simultaneously
  - Laser must have line of sight to entire track

Sintering

- Create a glass roadway using microwaves
  - Glass is stronger if the process is performed anhydrously

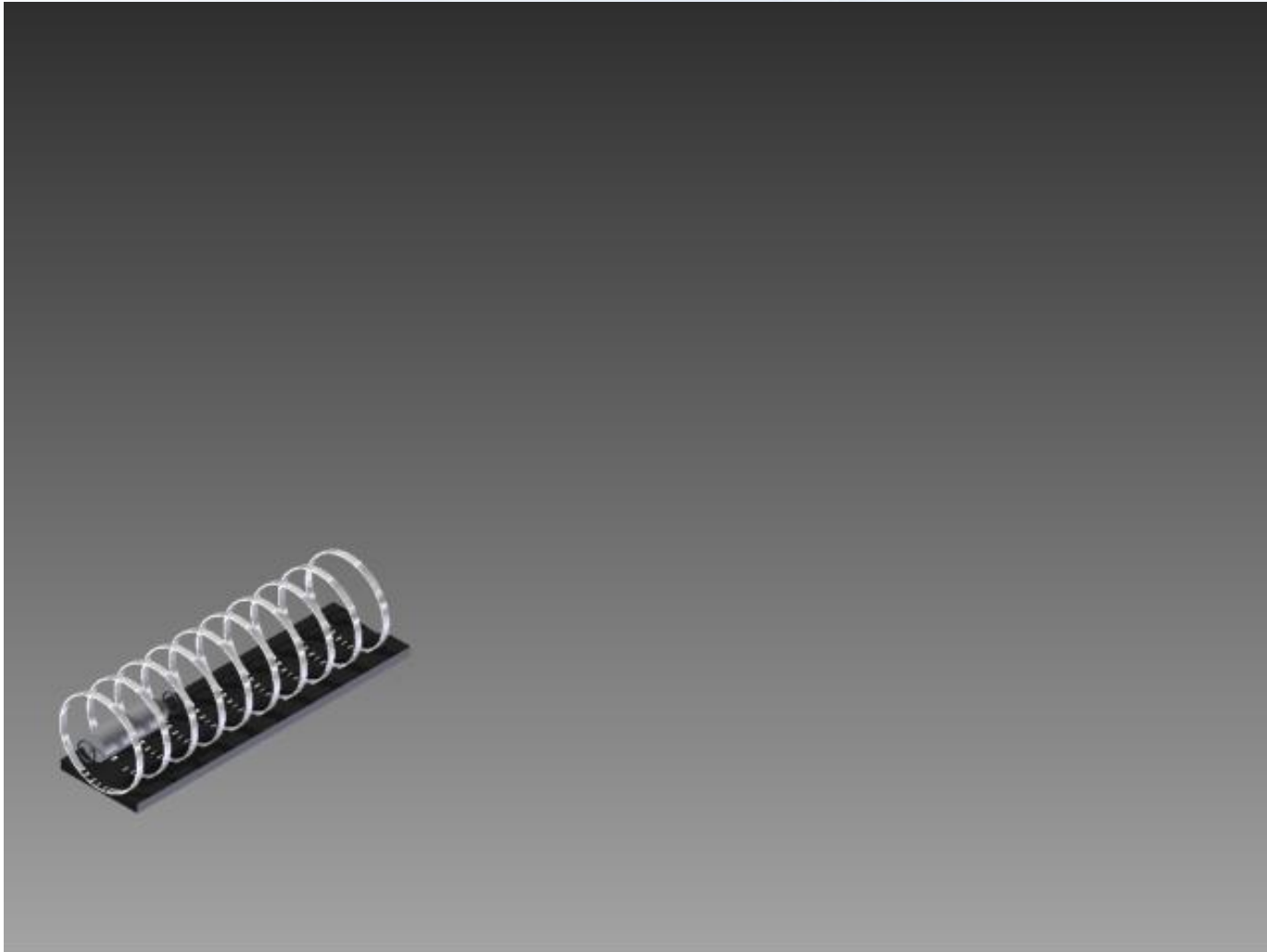- Use for the base/structure
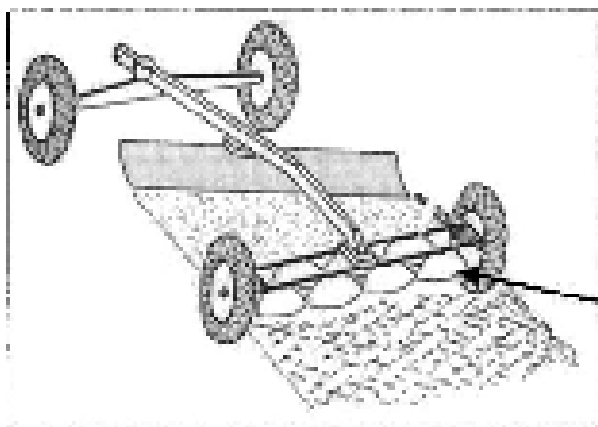
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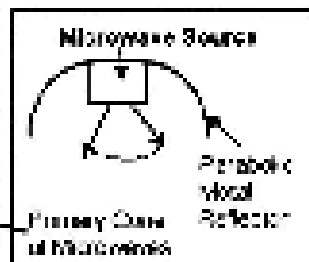
Power Beaming

- Need to beam ~268 GW power to the sled
  - 10.72 million lasers
    - 50yr out technology

  - Theoretical Maximum Efficiency: 50%
    - for light conversion
  - Large efficiency drop-off due to laser diffraction
    - 80% in 12 km

  - Emitter Radius: 21 m

Option 5: Coil Launcher

Option 5: Coil Launcher

- Characteristics:
  - Electromagnetic coils
  - In-situ materials
  - Simplified track design
  - Modular and flexible design
  - Reusable launching sled

- Design specifics:
  - Shipped mass – 620 tons
  - Coil diameter – 12.0 m
  - Coil spacing – 2.2 m

Design Options Recap

Option	Structure Design	In-Situ Resources	Key Advantages and Disadvantages	
Maglev 1	Track	✘	Proven Earth Technology	Everything Shipped
Maglev 2	Track	✔	Proven Earth Technology	Reduced Mass
LSM	Planar (minimal track)	✔	Reduced Structure	Complexity of Control
Conductive Glass Road	Planar Road	✔	Minimal Structure	Far Future Technology
Coil Launcher	Circular Coils	✔	Positions Cargo in Center	Complexity of Control

Mass and Launch Comparison

Option	Shipped Mass (tons)	Total Propellant Mass (tons)	Number of Equivalent NTR Missions
Maglev 1	44,797	219,751	1,112
Maglev 2	961	4,945	25
LSM	710	3,715	19
Conductive Glass Road	---	---	---
Coil Launcher	620	3,276	17

Cost Comparison

Option	Launch Cost ($ Billions)	Extraction Shipping Cost ($ Billion)	Total Shipping & Launch Cost ($ Billion)
Maglev 1	$ 261.32	---	$ 261.32
Maglev 2	$ 5.77	$ 63.61	$ 69.38
LSM	$ 4.26	$ 63.61	$ 67.87
Conductive Glass Road	---	---	---
Coil Launcher	$ 3.72	$ 63.61	$ 67.33

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Conclusions

- Advantages:
  - Variable ΔV
    - Additional launch missions
  - Launcher is more sustainable
    - After initial 17 payoff missions to Mars, uses less propellant per mission thereafter
  - Modular
    - Can add track/coils for longer/farther interplanetary missions in the future
    - If a small portion fails, it does not result in catastrophic failure of the whole system

Conclusions

- Challenges:
    - Significant upfront launch costs

    - Availability of lunar infrastructure

    - Significant investment in effort and time

Acknowledgements

- Dr. Steven Howe
- Center for Space Nuclear Research
- Center for Advanced Energy Studies
- Idaho National Labs
- United States Department of Energy
- University of Colorado Boulder
- University of Washington
- Penn State University
- Case Western Reserve University
- Tomball High School
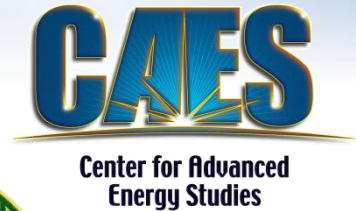
Questions?

Interplanetary Lunar Launcher

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